

इंटरनेट

मानक

Disclosure to Promote the Right To Information

Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

“जानने का अधिकार, जीने का अधिकार”

Mazdoor Kisan Shakti Sangathan

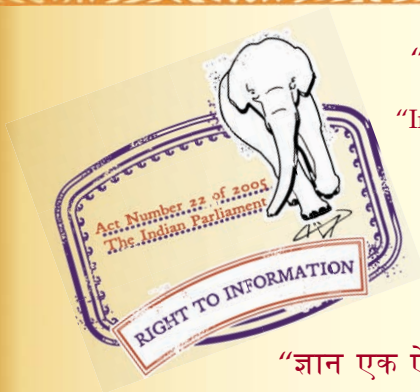
“The Right to Information, The Right to Live”

“पुराने को छोड़ नये के तरफ”

Jawaharlal Nehru

“Step Out From the Old to the New”

IS 13018 (1990): Internal Combustion Engines - Method of Test for Pressure Charged Engines [TED 2: Automotive Primemovers]



“ज्ञान से एक नये भारत का निर्माण”

Satyanarayan Gangaram Pitroda

“Invent a New India Using Knowledge”



“ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है”

Bhartrhari—Nitiśatakam

“Knowledge is such a treasure which cannot be stolen”

BLANK PAGE



भारतीय मानक

(Reaffirmed 2000)

अन्तर्दाही इंजन —
दाब आवेष्टित इंजनों की परीक्षण पद्धति

Indian Standard

**INTERNAL COMBUSTION ENGINES — METHOD
OF TEST FOR PRESSURE CHARGED ENGINES**

UDC 621.432.031 : 620.1

© BIS 1991

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

March 1991

Price Group 7

FOREWORD*

This Indian Standard was adopted by the Bureau of Indian Standards on 25 July 1990, after the draft finalized by the Automotive Prime Movers Sectional Committee had been approved by the Transport Engineering Division Council.

This Indian Standard is intended to meet the testing requirements of internal combustion engines of the pressure charged types with or without after cooler.

Internal combustion engines are being increasingly modified from the conventional designs in order to conserve energy, emitless pollutants in conformity with statutory regulations. Pressure charging the induction system by mechanical means with or without coolers is one such method. The principle involves increasing the density of air or mixture by mechanical means driven by engine itself or air exhaust turbine.

While test methods for naturally aspirated engines are adequately covered in IS 10000 series of standards, need had arisen to standardize testing methods for turbo-charged engines which are being used by Indian industries predominantly for stationary applications engaged in oil exploration, fertilizers, etc.

In the preparation of this Indian Standard considerable assistance has been derived from the following International standards:

ISO 3046 (Part 1) : 1986 Reciprocating internal combustion engines — Performance : Part 1
Standard reference conditions and declarations of power, fuel consumption and
lubricating oil consumption

ISO 3046 (Part 2) : 1977 Reciprocating internal combustion engines — Performance : Part 2
Test methods

ISO 3046 (Part 3) : 1979 Reciprocating internal combustion engines — Performance : Part 3
Test measurements

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

INTERNAL COMBUSTION ENGINES — METHOD OF TEST FOR PRESSURE CHARGED ENGINES

1 SCOPE

1.1 This Indian Standard specifies the test methods for pressure charged reciprocating internal combustion engines with and without after cooler.

1.2 Field of Application

The test methods specified in this standard are applicable to all internal combustion engines used for power generation, industrial equipment like earth movers.

1.3 Where no other suitable Indian Standards are available this standard may be applied for rail traction and marine engines.

2 REFERENCES

2.1 The following Indian Standards are necessary adjuncts to this standard:

<i>IS No.</i>	<i>Title</i>
1076 (Part 1) : 1985	Preferred numbers : Part 1 Series of preferred numbers (<i>second revision</i>)
10000 (Part 1) : 1980	Methods of tests for internal combustion engines : Part 1 Glossary of terms relating to test methods
10000 (Part 4) : 1980	Part 4 Declaration of power, efficiency, fuel consumption and lubricating oil consumption
10000 (Part 5) : 1980	Part 5 Preparation for tests and measurements for wear
10000 (Part 7) : 1980	Part 7 Governing tests for constant speed engines and for use with electrical generators
10000 (Part 9) : 1980	Part 9 Endurance tests

3 DEFINITIONS

Definitions wherever applicable shall be in accordance with IS 10000 (Part 1) : 1980. In addition, the following shall also apply.

3.1 Acceptance Test

This test is carried out as an overall check on the manufacturing quality, and to establish that the contractual commitments, have been fulfilled.

3.2 Type Test

This test is carried out on a representative engine of a particular engine type to establish the main performance data of the engine, and as far as possible, to enable their reliability and durability in service to be assessed.

3.3 Special Tests

These tests are carried out in addition to acceptance or type test to meet the requirements of inspecting and legislative authorities or purchasers.

NOTE — Special tests are subject to agreement between the manufacturer and purchasers.

3.4 Power Adjustment

It is the calculation procedure by which power at one set of ambient conditions is modified to represent the power expected under another set of ambient conditions. Power adjustment may result in engine adjustment.

3.5 Power Correction

It is the calculation procedure by which power determined under engine test conditions is modified so that it represents the power expected under other operational or reference conditions without any engine adjustment.

3.6 Engine Adjustment

A physical procedure of modifying an engine for the purpose of adopting it to a different set of ambient conditions, such as by moving the limiting fuel stop, re-matching the turbocharger changing the fuel injection timing or other mechanical changes.

4 STANDARD REFERENCE CONDITIONS

4.1 For the purpose of determining the power and fuel consumption of engines, the following standard reference conditions shall be used:

Total barometric pressure	100 kPa
Air intake temperature	298 K (25°C)
Charged air coolant temperature	298 K (25°C)
Relative humidity	30%

NOTE — Relative humidity of 30% of the corresponding barometric pressure is 99 kPa,

5 TEST CONDITIONS

5.1 General

5.1.1 The manufacturer shall submit the necessary technical documentation concerning the engine type and application, in case when mutually agreed between the manufacturer and the purchaser.

5.1.2 A period of running-in and preliminary tests considered adequate by the manufacturer shall precede the acceptance or type test.

5.1.3 The measurements for an acceptance or type test shall be carried out only when the engine has reached stable operating conditions as specified by the manufacturer.

5.1.4 Unless otherwise agreed between the manufacturer and the customer, test shall be carried out on a test bed at the manufacturer's works.

5.1.5 Tests shall be carried out on the engine equipped with dependent auxiliaries necessary for its operation either supplied with the engine or belonging to the test bed equipment.

5.1.6 Test bed equipment may be used, provided that the contractual requirements are fulfilled.

5.1.7 Only those engines which are supplied with built-in transmission systems (for example, hydraulic mechanism, reversing couplings) or electric generators, and which can not be tested separately, need to be tested with the transmission systems or generator coupled to the engine.

NOTE — If engines are tested coupled with a driven machinery or a transmission system which is separable, then any variation in power, due to these coupled items should be eliminated from a power declared system.

5.1.8 If the acceptance test is carried out on site and the rated speed can not be verified or achieved due to the special circumstances of the installation and/or situation of the installation, the manufacturer and the purchaser shall mutually agreed to the test report of the test carried out on the manufacturer's works test bed and verify only the declared speed at power other than rated power or power at speed other than the rated speed. In either case the measurement of the fuel consumption may be omitted.

5.1.9 During tests on the engine no additional adjustment, other than those required to maintain the test conditions and those required for normal operation as given in the instructions manual, may be made.

5.1.10 The only interruptions in testing permitted are those necessary for engine maintenance as given in the instructions manual. In all other cases, if an interruption should occur caused by some defect of parts of the engine, the decision on whether to repeat the tests partially or entirely shall

be agreed between the manufacturer and the purchaser.

5.1.11 In cases where it is not possible to maintain the specified ambient conditions and the fuel or fluid properties for the acceptance or type test, the influence of the differing conditions and/or properties and the necessary correction of test results shall be subject to agreement between the manufacturer and the purchaser.

NOTES

1 In dual-fuel engines the acceptance test is carried out with liquid fuel. An additional acceptance test with gaseous fuel may be stipulated by agreement if gaseous fuel is available at the manufacturer's works with approximately the same ignition characteristics as the gaseous fuel available on site.

2 In the case of spark-ignition gas engines and pilot injection gas engines, the acceptance test may be carried out at the manufacturer's works only if the composition and ignition characteristic of the gaseous fuel available are approximately the same as those of the gaseous fuel used on site.

3 If the acceptance test is to be carried out on the basis of a special agreement at the manufacturer's works with a gaseous fuel with chemical values and properties differing significantly from those on site the test can be made at agreed values of the rated power, rated speed and fuel consumption by resetting the engine accordingly. In such a case readjustment of the engine is necessary for the engine operation with the contractually specified gaseous fuel which is used on site.

5.1.12 Where applicable the declaration of power, fuel and lubricating oil consumption shall be in accordance with IS 10000 (Part 4) : 1980.

6 POWER ADJUSTMENT, SPECIFIC FUEL CONSUMPTION ADJUSTMENT AND POWER CORRECTION

6.1 The adjustment procedures are carried out when required to determine:

- a) Whether the values of power and fuel consumption attained under engine test ambient conditions correspond to the declared values.
- b) The permissible maximum power under test ambient conditions to prevent the engine overloading which excess air allows.

6.2 Two possible cases are recognized:

- a) Adjusted engines, where the power is adjusted to control limiting performance parameters when the ambient conditions differ from the standard reference conditions (for example, to maintain for an approximately constant thermal and/or mechanical load on critical engine components).
- b) Non-adjusted engines where the fuel settings are pre-set so that power and performance parameters may vary as a function of ambient condition.

6.3 Adjusted Engines

- a) Are those by adjusting the power from standard reference conditions to test ambient conditions.
- b) Are those by adjusting the declared service power from the site ambient conditions to the power under test ambient condition.
- c) Are those by making the test power equal to the declared service power and testing under conditions altered artificially according to 6.6 to simulate the site ambient condition.
- d) Are those by testing under condition simulating some of the site ambient condition according to 6.6 and adjusting the declared service power to allow for the remaining differences.

NOTE — When adjusting the power the engine manufacturer shall specify the formula used. If there is no suitable formula for power adjustment, the method of adjustment shall be mutually agreed between the manufacturer and the purchaser.

6.4 If a turbocharged engine at the declared power and under the standard reference conditions attain neither the turbocharger speed limit nor the exhaust gas temperature limit at the turbine inlet, the manufacturer may declare alternate reference conditions for the power adjustment.

6.5 When adjusting the site declared power for test ambient conditions, results may be attained where for example the maximum combustion pressure in the engine cylinder exceeds the permitted value. In this case the engine test shall be carried out at such a power, considered safe by the manufacturer at which the permitted value is not exceeded. The value of the engine parameters corresponding to the required power may be extrapolated from the measured values by a method to be agreed between the manufacturer and the customer.

6.6 Engine tests may be carried out under ambient conditions created artificially to simulate site ambient conditions. The following methods may be used:

- a) Throttling of the engine (turbocharger) inlet with simultaneous depression at the outlet and in the crank-chamber by an extractor device. Maximum vacuum shall not exceed the limits set by the turbocharger manufacturer.
- b) Increasing the air temperature at the engine inlet by artificial heating.
- c) Altering the coolant temperature at the inlet of the charge air cooler, etc.
- d) On pressure-charged engines having a charge air cooler, the effect of increased

ambient temperature can be easily simulated by throttling at the turbocharger inlet and controlling the air temperature after the charge air cooler to be the same as that on site. The throttle ratio can be determined by using Fig. 1.

6.6.1 Examples illustrating how power adjustment, specific fuel consumption adjustment and simulation of high on site ambient temperature are applied when testing, are given in Annex A.

6.7 Non-Adjusted Engines (Engines with pre-set fuel settings). Where the test conditions differ from the standard reference conditions, the method in 8 shall be used for power corrections of measured power to standard reference conditions (correction by calculation).

6.7.1 The manufacturer shall specify which method (power adjustment or power correction) is applicable to his engine with respect to 6.7.2.

6.7.2 In general, the power and specific fuel consumption shall be adjusted or corrected if any of the ambient conditions under which the engine operates during test or on site differ from the standard reference conditions. The amount by which the test conditions may differ from the standard reference conditions without affecting the power and the specific fuel consumption depends for example on the engine design, air excess, engine speed and its thermal load. In such cases the engine manufacturer shall indicate the specific amounts by which the test or site ambient conditions may differ from the standard reference conditions without the necessity of adjusting or correcting the power and the specific fuel consumption.

7 TESTS

7.1 The sequence of acceptance and type tests shall be established by the manufacturer.

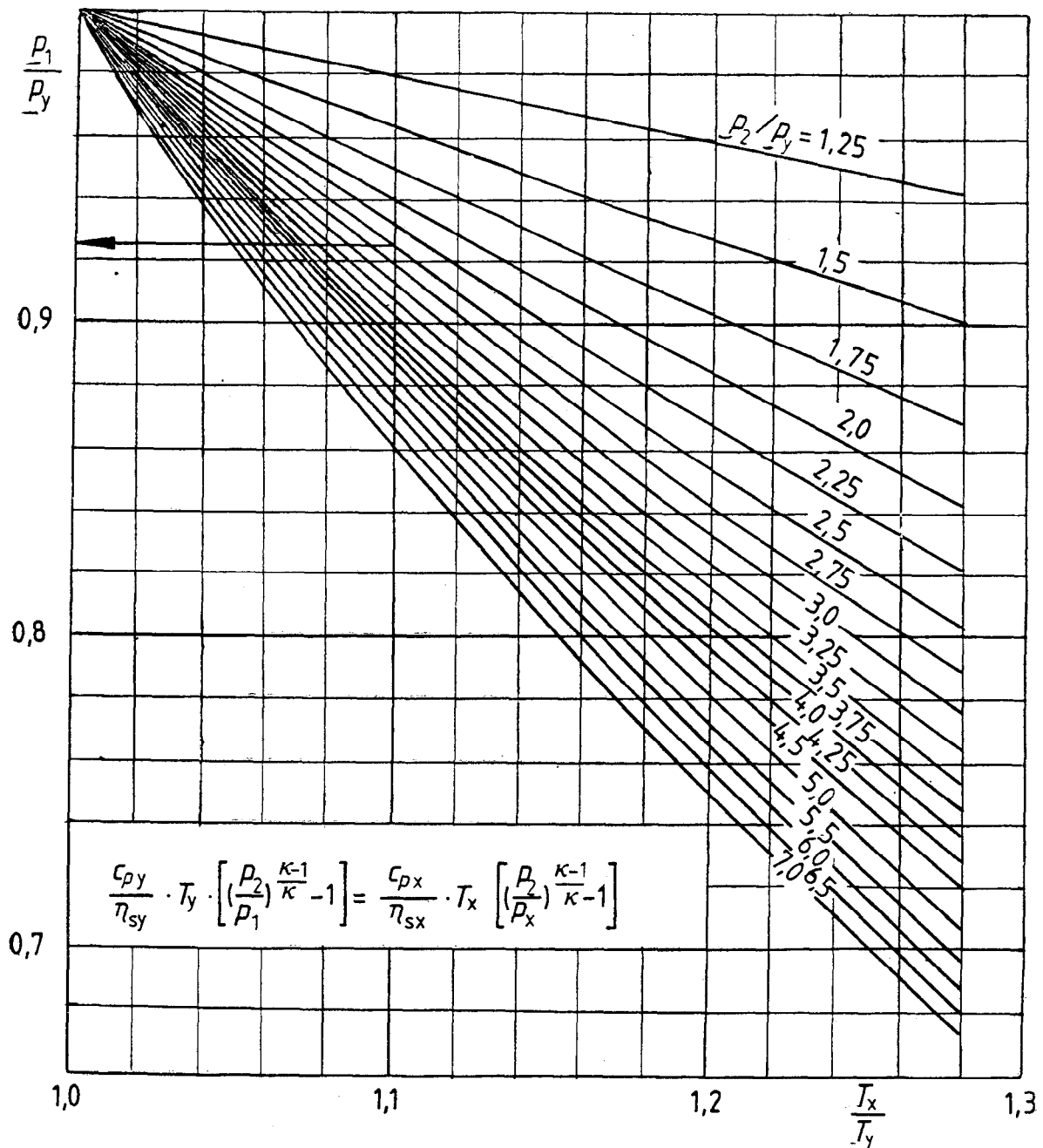
7.2 It is the responsibility of the manufacturer to define the extent of measurements, which shall be agreed with the customer. Table 1 may be taken as a guide for selecting the engine groups appropriate to the test measurements given in Table 2.

7.3 For mass-produced engines not all tested on load, an adequate inspection procedure may be used instead of a full acceptance test.

7.4 Dependent on the test categories and the engine group number, recommended test measurements, calculated values and functional checks are given in Table 2.

8 POWER CORRECTION FACTOR AND METHOD

The power correction method with pre-set settings and engine speeds of $2\,000\text{ min}^{-1}$ and above is generally applicable. However, the method may be extended to other types of engines as considered appropriate.



P_y test ambient pressure
 P_x site ambient air pressure
 P_1 air pressure after throttle
 P_2 air pressure at the compressor outlet
 T_y test ambient temperature
 T_x site ambient temperature
 K adiabatic index
 C_{py} test heat capacity at constant pressure
 C_{px} site heat capacity at constant pressure
 η_{sy} test adiabatic compressor efficiency
 η_{sx} site adiabatic compressor efficiency
 Δh_y test enthalpy difference
 Δh_x site enthalpy difference

NOTES

1 Example 2 in A-2 of the Annex provides an example of the application of Fig. 1.

2 The following conventional assumptions are made:

- equal compressor work;
- equal pressure at the compressor outlet;
- equal charge air temperature after cooler;
- equal air consumption through compressor;
- difference between C_{py} and C_{px} is neglected;
- adiabatic compressor efficiency is taken constant.

FIG. 1 DETERMINATION OF DEPRESSION AT COMPRESSOR INLET WHEN SIMULATING HIGH ON-SITE AIR TEMPERATURE

The power correction factor α is a factor by which the measured power shall be multiplied to determine the engine power under the standard reference conditions. The power corrected to the

standard reference conditions. P_r may be calculated as follows:

$$P_r = \alpha_a \times P_y \text{ (for spark-ignition engines)}$$

or $P_r = \alpha_d \times P_y \text{ (for compression-ignition engines)}$

where

P_y is the power observed (determined) on the test bed;

α_a is the correction factor spark-ignition engines;

α_d is the correction factor for compression-ignition engines.

NOTES

1 Tests may be carried out in air conditioned test rooms so that the atmospheric conditions may be controlled.

2 Examples illustrating how correction factors are applied when testing engines with pre-set fuel settings are given in Annex B.

Table 1 Measurement Selection Guide

(Clause 7.2)

Engine Group Number	Typical Characteristics of Engine Group
1	Engine the operating conditions of which are not measured in service, usually with maximum design speeds of more than 1 800 min ⁻¹
3	Pressure charged engines with maximum design speeds of approximately 2 500 min ⁻¹ and above
4	Engines with maximum design speeds of approximately 250 to 1 500 min ⁻¹
5	Engines with maximum design speeds up to 250 min ⁻¹

Table 2 Test Measurement Parameters

(Clauses 7.2, 7.4, 10.1.1, 10.1.3, 10.1.4, 10.1.5, 10.2.2 and 10.3.1)

Parameter to be Measured	Engine Group Number (see Table 1)			
	1	3	4	5
Barometric pressure, humidity and ambient temperature	×	×	×	×
Engine speed or cycle frequency	×	×	×	×
Engine brake torque and/or fuel pump or governor throttle control rod setting	×	×	×	×
Fuel consumption		×	×	×
Lubricating oil pressure		×	×	×
Temperature and pressure of exhaust gas leaving the engine		×	×	×
Air intake pressure and temperature at the engine or pressure charger inlet		×	×	×
Exhaust gas temperature at the turbine inlet		×	×	×
Boost pressure in the air manifold		×	×	×
Turbocharger speed		×	×	×
Coolant mean temperature at the engine cylinder block		×	×	×
Lubricating oil temperature at the engine inlet and outlet		×	×	×
Boost pressure drop through the air cooler		×	×	×
Boost pressure after each air cooler		×	×	×
Charge air temperature after each air cooler		×	×	×
Coolant mean temperature at the charge air cooler inlet and outlet		×	×	×
Maximum cylinder pressure			×	×
Exhaust gas pressure at the turbine inlet		×	×	×
Exhaust gas temperature of each cylinder			×	×
Individual coolant circuit temperature and pressures			×	×
Lubricating oil pressure individual circuits (example, turbocharger, piston cooling, etc)			×	×
Lubricating oil pressure before and after filters and coolers			×	×
Secondary coolant and lubricating oil temperatures in and out of heat exchangers			×	×
Fuel supply pressure and temperature			×	×
Compression pressure				×

NOTES

- Additional items may be included by agreement between the manufacturer and the customer.
- The ratings of engine shall conform to R 20 series in accordance with IS 1076 (Part 1) : 1985.

8.1 Correction Factor α_a for Spark-Ignition Engines

The correction factor, α_a , is calculated from the following equation:

$$\alpha_a = \left(\frac{p_r - \phi_y P_{sy}}{p_y - \phi_y P_{sy}} \right)^{1.2} \left(\frac{T_y}{T_r} \right)^{0.6}$$

where

T = absolute air temperature in kelvins at the air inlet to the engine (within 150 mm of entry to the air cleaner),

p = total barometric pressure in kilopascals,

p_s = saturated vapour pressure in kilopascals at the applicable temperature (at $\phi = 100\%$), and

ϕ = relative humidity.

Subscript 'r' corresponds to values under standard reference conditions.

Subscript 'y' corresponds to values under test ambient conditions.

This formula is only applicable if the correction factor α_a is between 0.93, and 1.07, the ambient temperature at the air inlet to the engine is $T_r \pm 10^\circ \text{C}$ and the dry barometric pressure is 80 to 110 kPa. If these limits are exceeded the corrected value obtained shall be given, and the test ambient conditions (temperature and pressure) precisely stated in the test report.

NOTE — In the case of engines fitted with automatic air temperature control, if the device is fully closed at full load at 25°C (no heated air added to the intake air) the test is carried out with the device fully closed and the normal correction factor applied. If the device still operating at 25°C then the test is made with the device operating normally and the exponent of the temperature term in the correction factor may be taken as zero (no temperature correction).

8.2 Correction Factor (α_d) for Compression-Ignition Engines

The power correction factor, α_d , for compression-ignition engines with pre-set fuel settings is obtained by the following equation:

$$\alpha_d = (f_a)^{f_m}$$

where

f_a = the atmospheric factor;

f_m = the engine factor (characteristic parameter for each type of engine).

8.2.1 Atmospheric Factor (f_a)

This factor indicates the effect of environmental conditions (pressure, temperature and humidity) on the air drawn in by the engine. The atmospheric factor equation differs according to the type of engine.

For mechanically pressure charged engines, the following equation applies:

$$f_a = \left(\frac{P_r - \phi_y P_{sr}}{P_y - \phi_y P_{sy}} \right) \left(\frac{T_y}{T_r} \right)^{0.7}$$

For turbocharged engines with or without charge air cooling, the following equation applies:

$$f_a = \left(\frac{P_r - \phi_r P_{sr}}{P_y - \phi_y P_{sy}} \right)^{0.7} \left(\frac{T_y}{T_r} \right)^{1.5}$$

NOTE — For symbols and subscripts, see 8.8.1.

8.2.2 Engine Factor, f_m

This factor is dependent upon the type of engine and the trapped air/fuel ratio corresponding to the fuel setting.

The engine factor f_m is a function of q_0 as follows:

$$f_m = 0.036 q_0 - 1.14$$

in which

$$q_0 = \frac{q}{\pi}$$

where

q_0 = is corrected fuel delivery per cycle (mg/ litre),

q = is the fuel delivery per cycle measured in milligrams per litre of total swept volume; mg/l), and

π = is the ratio of absolute pressure of compressor outlet to that of compressor inlet.

NOTE — For two stage turbocharging, it shall be the overall pressure ratio.

This formula is valid for the following value interval of q_0 .

$$40 \leq q_0 \leq 65$$

For q_0 values lower than 40, a constant value of f_m equal to 0.3 ($f_m = 0.3$) will be taken. For q_0 values higher than 65, a constant value of f_m equal to 1.2 ($f_m = 1.2$) will be taken (see Fig. 2).

8.2.3 Limitation in Use of the Correction Formula

The correction formula in 8.2 is only applicable where the correction factor α_d is between 0.9 and 1.1, the ambient temperature of the air inlet of the engine is $T \pm 15^\circ\text{C}$ and the dry barometric pressure is 80 to 110 kPa. If these limits are exceeded the correction value obtained shall be given and test ambient conditions (temperature and pressure) precisely stated in the test report.

8.3 Specific Fuel Consumption Adjustment Factor ' β '

It is the ratio of the specific fuel consumption under site conditions to the specific fuel consumption under standard reference conditions.

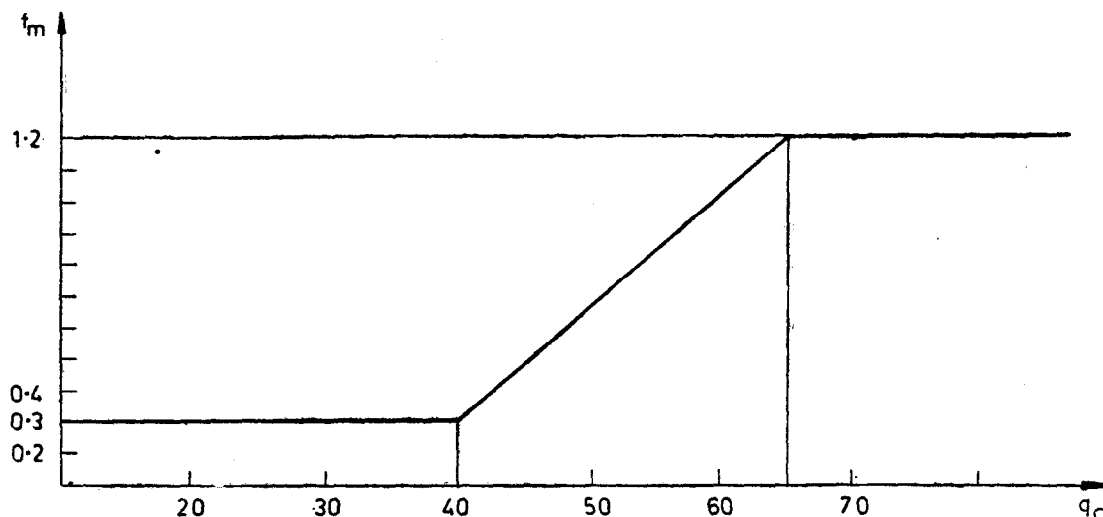


FIG. 2 ENGINE FACTOR f_m AS A FUNCTION OF THE CORRECTED FUEL DELIVERY, q_c

9 MEASUREMENT PARAMETERS, UNITS AND LIMITS OF ACCURACY

9.1 Units and Limits of Accuracy

Shall be as per Annex C.

10 TEST PROCEDURES

10.1 Acceptance Test

10.1.1 Acceptance tests comprise a specified sequence of power settings with measurements and calculated values given in Table 2 and **10.1.4** and the functional checks given in **10.1.5.1**.

10.1.2 The duration of the total acceptance test depends on the engine power and applications.

10.1.3 Normally measurements in Table 2 shall be made according to the specified engine group for each operating condition wherever appropriate and where provision exists on the engine for doing so. Where measurements are carried out for the purpose of verifying the declaration of power, engine speed and fuel consumption, valid measurements shall be carried out at least twice. A measurement shall be considered valid if the variations of the engine brake torque and engine speed values in relation to the settings of the operating values do not exceed $\pm 2\%$. The variation of the power output during this period shall not exceed $\pm 3\%$. This requirement shall not normally apply to spark ignition engines with a brake power less than 50 kW. Measurements in Table 2 are arranged in an ascending order of test measurement complexity and are presented for guidance when the contract is drawn up between the manufacturer and the customer. Either party may, by agreement, add to or delete from the measurements in Table 2 to suit the particular type of engine involved. Where no provision

exists on the engine for a particular measurement, it shall be stated so by the manufacturer.

10.1.4 Where appropriate, the manufacturer shall supply the calculated values given on the basis of test measurement obtained from Table 2. In additions the following comprise of design values and are not required to be demonstrated during acceptance test. The manufacturer shall supply the calculated values if required by the purchaser.

- a) Turbocharger speed;
- b) Boost pressure drop through the air cooler;
- c) Boost pressure after each air cooler;
- d) Charge air temperature after each air cooler;
- e) Maximum cylinder pressure;
- f) Exhaust gas temperature at turbine inlet;
- g) Brake power;
- h) Temperature and pressure of exhaust gas leaving the turbine;
- j) Coolant mean temperature at the charge air cooler inlet and outlet; and
- k) Brake specific fuel consumption.

10.1.4.1 The measurement of the fuel consumption shall be carried out during the measurement of power.

10.1.4.2 For engines having a brake power of 200 kW and above, if the variation between the results of two fuel consumption measurement is more than 2 percent the measurement shall be repeated for this operating condition.

10.1.4.3 Fuel fed to the engine which is surplus and not consumed shall be taken into account in the measurement accordingly.

10.1.5 Functional Checks

Comprises functional checks which may additionally be carried out on engines in groups 3 to 5 in Table 2. The selection from 10.1.5.1 shall be agreed between the manufacturer and the purchaser.

10.1.5.1 Checks shall be carried out to demonstrate the following:

- a) The correct functioning of the overspeed limiting device;
- b) The correct functioning of the speed governing system [see IS 10000 (Part 7) : 1980].
- c) The ability of all malfunction protection and warning devices to respond correctly to the fault conditions in which they should operate (for example, low lubricating oil pressure, high lubricating oil temperatures, high coolant temperatures, pressure rise in the engine crankcase, etc).
- d) The correct functioning of all automatic pressure and temperature controls.
- e) The ability of the starting system to perform prior to and/or after the acceptance test conditions of the engine are reached subject to agreement between manufacturer and customer.
- f) The correct functioning of the reversing mechanism, built-in reverse reduction gear and couplings.
- h) That the temperature of important components is satisfactory.
- j) Crank web deflection.
- k) Stability of the engine on its support.
- m) The condition after test of one or more piston and cylinder assemblies and bearings chosen by inspection.

NOTE — Additional checks may be included by agreement between the manufacturer and the purchaser.

10.2 Type Tests

10.2.1 A type test comprises a specified sequence of power/engine speed combined values, reversals and stop.

10.2.2 Type tests shall include, as far as applicable, all measurements, calculations and functional checks in Table 2, engine group 5, and 10.1.4, 10.1.5 to 10.2.2.1.

10.2.2.1 The measurements shall include:

- a) Air consumption;
- b) Fuel and lubricating oil consumption [see IS 10000 (Part 4) : 1980].

- c) Dismantling, inspection and measuring of important parts subject to wear [see IS 10000 (Part 5) : 1980].

10.2.2.2 Type tests are to be carried out on a representative basic engine type to establish the main performance data of the engine and as far as possible, to enable their reliability and durability in service to be assessed.

10.3 Endurance Test

Shall be carried on an engine equipped with all dependent auxiliaries necessary for its operation either suggested with the engine or belonging to test bed equipment.

10.3.1 The test shall be carried out in accordance with IS 10000 (Part 9) : 1980, after the preliminary run and initial performance tests. The parameters to be measured during the tests shall be in accordance with Table 2 (see 5.1.2).

10.3.2 The final performance shall be carried out after the endurance test. The engine shall be dismantled and wear of the components shall be measured.

10.4 Special Test

Special test are any of those in 10.4.1 which may be carried out as agreed to between the manufacturer and the purchaser (see 3.3).

10.4.1 Typical Examples

- a) Torsional vibration frequencies and amplitudes at set power/engine speed combinations when the engine is tested coupled to its contract driven machinery.
- b) Engine heat balance.
- c) Sound level.
- d) Exhaust gas emission characteristics.
- e) Test in conjunction with contract driven machinery.
- f) Parallel running and other electrical tests of engine-driven generator.
- g) Emergency reversal as in case of marine engines.
- h) Determination of minimum stable speed of marine engines.
- j) Changeover on dual-fuel engines.
- k) Ability to carry out maintenance tasks within the time stated by the manufacturer.
- m) Ability to manoeuvre and provide a stated power when operating with specified malfunctions, for example, with one or more turbochargers inoperative.

11 TEST REPORT

11.1 The manufacturer shall provide a test report.

11.1.1 Normally, acceptance test reports shall be provided for engine group numbers 3 and 5 only.

11.1.2 Type test reports shall be provided for all groups of engines.

11.2 The test report shall include engine identification and the following test information:

- Reference to this Indian Standard.
- Date, place, designation of test and inspecting authority.
- Type of fuel and lubricating oils used during test.

NOTE — *Quality of fuel:*

If the fuel used complies with the specification of a national or international standard, the properties need be verified only by explicit agreement between the manufacturer and the purchaser.

If the fuel does not comply with the specification of a national or international standard, the properties and constituents should be stated as agreed between the manufacturer and the customer.

The lower calorific value of the fuel and its method of determination should be stated.

- Dependent auxiliaries, engine settings and proprietary equipment.
- Table of values measured during the test.
- Interpretation of certain measurements as required.

ANNEX A

(Clause 6.6.1)

EXAMPLES OF POWER ADJUSTMENT, SPECIFIC FUEL CONSUMPTION ADJUSTMENT AND SIMULATION OF HIGH ON-SITE AMBIENT TEMPERATURE FOR ADJUSTED ENGINES WITH ADJUSTED FUEL SETTINGS

A-1 EXAMPLE 1

A four-stroke turbocharged compression-ignition engine with charge air cooling will develop 640 kW net brake power under site ambient conditions, where

$$\begin{aligned} P_x &= 70 \text{ kPa} \\ T_x &= 330 \text{ K} \\ T_{cx} &= 300 \text{ K} \\ \eta_m &= 0.85 \end{aligned}$$

What power should be developed under test ambient conditions, where

$$\begin{aligned} p_y &= 100 \text{ kPa} \\ T_y &= 300 \text{ K} \\ T_{cy} &= 280 \text{ K} \end{aligned}$$

Initially, the engine power developed under site ambient conditions will be adjusted to the standard reference conditions, and then the results attained will be adjusted to test ambient conditions.

The first step in solving the example is to determine what the brake power output is at standard reference conditions.

The general equations shall be redefined so the site ambient conditions can be adjusted to standard reference conditions.

To adjust net brake power, P_x , at site ambient conditions to net brake power at standard

reference conditions, P_r :

$$P_x = \alpha_r P_r$$

where

P_x is the net brake power at site ambient conditions (640 kW);

α_r is the power adjustment factor for adjustment to standard reference conditions; and

P_r is the net brake power at standard reference conditions.

The power adjustment factor, α_r , for adjusting site ambient conditions to standard reference conditions is:

$$\alpha_r = k_r - 0.7 (1 - k_1) \left(\frac{1}{\eta_m} - 1 \right)$$

where

k_r is the power ratio for adjustment to standard reference conditions;

η_m is the mechanical efficiency (0.85).

The power ratio, k_r , needed for adjustment from site ambient conditions to standard reference conditions is:

$$k_r = \left(\frac{p_x}{p_r} \right)^m \left(\frac{T_r}{T_x} \right)^n \left(\frac{T_{cr}}{T_{cx}} \right)^q$$

where

k_r is the ratio of indicated power of adjustment to standard reference condition;

p_r is the standard reference total barometric pressure (100 kPa);

T_r is the standard reference absolute air temperature (298 K);

T_{cr} is the standard reference absolute charge air coolant temperature (298 K);

p_x is the total barometric pressure at site (70 kPa);

T_x is the ambient temperature at site (330 K);

T_{cx} is the charge air temperature at site (300 K);

$$m = 0.7;$$

$$n = 1.2; \text{ and}$$

$$q = 1.0$$

Using the formulae that have been developed and substituting the values given in the example:

$$k_r = \left(\frac{70}{100} \right)^{0.7} \left(\frac{298}{330} \right)^{1.2} \left(\frac{298}{300} \right)^{1.0} = 0.684$$

$$\begin{aligned} \alpha_r &= 0.684 - 0.7 (1 - 0.684) \left(\frac{1}{0.85} - 1 \right) \\ &= 0.684 - (0.7 \times 0.316 \times 0.18) \\ &= 0.644 \end{aligned}$$

Therefore, the power in kilowatts is

$$P_r = \frac{640}{0.644} = 994$$

This is the power output at standard reference conditions.

The next step is to adjust the power to test ambient conditions,

where

P_y is the power under test ambient conditions;

p_y is the total barometric pressure at test ambient conditions;

T_y is the temperature at test ambient conditions;

α_y is the power adjustment factor for adjustment from standard reference to test ambient conditions;

k_y is the ratio of indicated power for adjustment from standard reference to test ambient conditions.

The formulae for adjusting from standard reference conditions to test ambient condition are:

$$P_y = \alpha_y P_r$$

$$\alpha_y = k_y - 0.7 (1 - k_y) \left(\frac{1}{\eta_m} - 1 \right)$$

$$k_y = \left(\frac{p_y}{p_r} \right)^m \left(\frac{T_r}{T_y} \right)^n \left(\frac{T_{cr}}{T_{cy}} \right)^q$$

Substituting,

$$\begin{aligned} k_y &= \left(\frac{100}{70} \right)^{0.7} \left(\frac{298}{330} \right)^{1.2} \left(\frac{298}{280} \right)^{1.0} \\ &= 1.056 \end{aligned}$$

$$\begin{aligned} \alpha_y &= 1.056 - 0.7 (1 - 1.056) \left(\frac{1}{0.85} - 1 \right) \\ &= 1.056 + 0.7 (0.056 \times 0.18) = 1.063 \end{aligned}$$

Therefore the power, in kilowatts, is

$$P_y = 1.063 \times 994 = 1.054$$

If there is a limitation in the maximum allowable combustion pressure, say, at 808 kW, and the manufacturer so decides, the engine shall be tested under loads up to but not exceeding 808 kW.

A-2 EXAMPLE 2

The engine from example 1 is required to be tested under conditions simulating site ambient conditions, for example at a higher test ambient temperature $T = 330$ K and a pressure ratio

$\frac{p_2}{p_1}$ of 2.5. Using the inlet air throttling method, determine what power must be developed on the test bed and the pressure behind the throttle plate necessary to simulate the site ambient conditions.

In simulating the higher test ambient temperature using the throttling method, the air temperature after the charge air cooler will be equal to that reached under site ambient conditions. The temperature or coolant flow control at the charge air cooler inlet shall be adjusted accordingly.

$$P_y = \alpha_y P_x$$

where

P_y is the power to be developed on the test bed;

α_y is the power adjustment factor for simulating site ambient conditions on the test bed; and

k_y is the ratio of indicated power for simulating site ambient conditions on the bed.

The ratio of indicated power for the example would be:

$$k_y = \left(\frac{p_y}{p_x} \right)^m \left(\frac{T_x}{T_y} \right)^n \left(\frac{T_{cx}}{T_{cy}} \right)^q$$

Because in using the throttling method the test

bed air temperature after the charge air cooler equals that of the site, the last two terms become equal to one, so the resulting equation becomes

$$k_y = \left(\frac{p_y}{p_x} \right)^m$$

where

p_y is the test ambient pressure; and

p_x is the site ambient pressure.

Substituting the given values

$$k_y = \left(\frac{100}{70} \right)^{0.7} = 1.28$$

The power adjustment factor would be :

$$\alpha_y = k_y - 0.7 (1 - k_y) \left(\frac{1}{\eta_m} - 1 \right)$$

Substituting the given values

$$\begin{aligned} \alpha_y &= 1.28 - 0.7 (1 - 1.28) \left(\frac{1}{0.85} - 1 \right) \\ &= 1.28 + 0.7 (0.28 \times 0.18) \\ &= 1.315 \end{aligned}$$

Using the calculated values, the power output, in kilowatts, to be measured on the test bed becomes :

$$p_y = 1.315 \times 640 = 842$$

To determine what the pressure behind the throttle plate shall be to simulate site ambient conditions, Fig. 1 is used, where

$$\frac{T_x}{T_y} = \frac{330}{300} = 1.10$$

Using this value and the given pressure ratio $\frac{p_2}{p_y}$

$$\begin{aligned} &= 2.5 \text{ the value for } \frac{p_1}{p_y} \text{ from Fig. 2 is } \frac{p_1}{p_y} \\ &= 0.925. \end{aligned}$$

The air pressure, p_1 after the throttle, in kilopascals, is then calculated by substituting the test ambient pressure, p_y into the equation:

$$p_1 = 0.925 \times 100 = 92.5$$

If the measured fuel consumption at 838 kW is 238 g/(kW·h), then the fuel consumption adjusted to site ambient conditions can be determined with the equation

$$b_x = \frac{b_y}{\beta_y}$$

where

b_x is the specific fuel consumption at site ambient conditions;

b_y is the specific fuel consumption at test ambient conditions:

$$\beta_y = \frac{k_y}{\alpha_y}$$

Substituting

$$\beta_y = \frac{1.28}{1.315} = 0.973$$

Then the specific fuel consumption at the site conditions in grams per kilowatt hour will be

$$b_x = \frac{238}{0.973} = 245$$

ANNEX B

(Clause 8)

EXAMPLES OF POWER CORRECTION FOR NON-ADJUSTED ENGINES (ENGINES WITH PRE-SET FUEL SETTINGS)

B-1 EXAMPLE 1

A four stroke turbocharged compression ignition engine with charge air cooling will develop 896 kW at test ambient conditions. What is the corrected power expected at the listed site ambient conditions. The engine speed is 1 800 min⁻¹, total swept volume is 51.8 litre and fuel delivery is 54.5 g/s. The turbocharger pressure ratio of compressor outlet to compressor inlet is 2.6.

Test ambient conditions

$$p_y = 96 \text{ kPa}$$

$$T_y = 302 \text{ K}$$

$$\phi_y = 0.2$$

Site ambient conditions

$$p_x = 98 \text{ kPa}$$

$$T_x = 315 \text{ K}$$

$$\phi_x = 0.4$$

From 8

$$P_x = \alpha_d \times P_y$$

From 8.2

$$\alpha_d = (f_a)^{\gamma_m}$$

From 8.2.1

$$f_a = \left(\frac{p_x - \phi_x p_{sx}}{p_y - \phi_y p_{sy}} \right)^{0.7} \left(\frac{T_y}{T_x} \right)^{1.5}$$

From 8.2.2

$$f_m = 0.036 q_c - 1.14$$

$$\text{where } q_c = \frac{q}{\pi}$$

The first step is to determine the value of fuel delivery, q in mg/litre/cycle

$$q = \frac{(1000 \times 60 \times 2)(54.5)}{(51.8 \times 1800)} = 70.14$$

Therefore

$$q_c = \frac{70.14}{2.6} = 27$$

Because q_c is less than 40, $f_m = 0.3$

Next determine a value for f_a

$$f_a = \left(\frac{98 - 3.3}{96 - 0.83} \right)^{0.7} \left(\frac{302}{315} \right)^{1.5} = 0.935$$

Next calculate for α_d

$$\alpha_d = 0.935^{0.8} = 0.980$$

Then the power, in kilowatts, is

$$P_x = 0.980 \times 896 = 878$$

This is the power that will be developed at site ambient conditions.

B-2 EXAMPLE 2

A four-stroke turbocharged compression-ignition engine without charge air cooling with a mechanical efficiency of 0.85 will develop 700 kW at test ambient conditions. What is the corrected power expected at the listed site ambient condition? The engine speed is 1200 min⁻¹, total swept volume is 45 litres and fuel delivery is 51.3 g/s. The turbocharger pressure ratio of compressor outlet to compressor inlet is 2.0.

Test ambient conditions

$$p_y = 96 \text{ kPa}$$

$$T_y = 302 \text{ K}$$

$$\phi_y = 0.2$$

Site ambient conditions

$$p_x = 69 \text{ kPa}$$

$$T_x = 283 \text{ K}$$

$$\phi_x = 0.4$$

Standard reference conditions

$$p_r = 100 \text{ kPa}$$

$$T_r = 298 \text{ K}$$

$$\phi_r = 0.3$$

Following the same steps as in example 2, the fuel delivery, q , in milligrammes per litre cycle is

$$q = \frac{(1000 \times 60 \times 2)(51.3)}{(45 \times 1200)} = 114$$

Hence

$$q_c = \frac{114}{2.0} = 57$$

$$f_m = (0.036 \times 57) - 1.14 = 0.912$$

$$f_a = \left(\frac{69 - 0.5}{96 - 0.83} \right)^{0.7} \left(\frac{302}{283} \right)^{1.5} = 0.876$$

Therefore

$$\alpha_d = (0.876)^{0.912} = 0.886$$

According to the limitation in 8.2.3, the 8.2 equations cannot be used to correct directly from test ambient to site ambient conditions.

The correction shall be made in two steps — first using 8.2 equations to correct from test ambient condition to standard reference conditions and then using equations to adjust from standard reference conditions to site ambient conditions.

Using the equations from 8.2

$$q_c = 57$$

and

$$f_m = 0.912$$

The value of f_a for correction from test ambient to standard reference conditions is calculated as follows

$$f_a = \left(\frac{100 - 0.95}{96 - 0.83} \right)^{0.7} \left(\frac{302}{298} \right)^{1.5} = 1.05$$

Therefore

$$\alpha_d = (1.05)^{0.912} = 1.045$$

and the power, in kilowatts, is

$$P_r = 1.045 \times 700 = 732$$

This is the power expected at standard reference conditions.

Now the power can be corrected from standard reference conditions to site ambient conditions by using equations (1), (2) and (3)

$$P_x = \alpha P_r \quad \dots (1)$$

$$\alpha = k - 0.7(1 - k) \left(\frac{1}{\eta_m} - 1 \right) \dots (2)$$

and

Substituting

$$k = \left(\frac{p_x}{p_r} \right)^m \left(\frac{T_r}{T_x} \right)^n \left(\frac{T_{or}}{T_{er}} \right)^q \quad \dots (3)$$

$$m = 0.7; n = 2 \text{ and } q = 0$$

$$k = \left(\frac{69}{100} \right)^{0.7} \left(\frac{298}{283} \right)^2 = 0.855$$

$$\alpha = 0.855 - 0.7 (0.145 \times 0.18) = 0.837$$

$$P_x = 0.837 \times 732 = 613$$

This is the expected power, in kilowatts, at site ambient conditions.

ANNEX C

(Clause 9.1)

MEASUREMENT PARAMETERS, UNITS AND LIMITS OF ACCURACY

No.	Parameter	Symbol	Unit	Accuracy
1	2	3	4	5
C-1	General parameters			
C-1.1	Engine torque	T_{tq}	kN.m	$\pm 2 \%$
C-1.2	Rotational frequency of engine (engine speed)	n	s^{-1} (r/min)	$\pm 2 \%$
C-1.3	Rotational frequency of engine driving shaft (engine driving shaft speed)	n_d	s^{-1} (r/min)	$\pm 2 \%$
C-1.4	Brake power	P_e	kW	$\pm 3 \%$
C-2	Pressures*			
C-2.1	Barometric pressure	P_a	kPa	$\pm 0.5 \%$
C-2.2	Compression pressure in a cylinder	P_c	kPa	$\pm 5 \%$
C-2.3	Maximum pressure in a cylinder	P_{max}	kPa	$\pm 5 \%$
C-2.4	Air pressure at the engine or pressure charger inlet			
C-2.4.1	Depression at engine or pressure charger inlet	ΔP_k	kPa	$\pm 5 \%$
C-2.4.2	Absolute pressure at engine or pressure charger inlet	P_k	kPa	$\pm 1 \%$
C-2.5	Boost pressure after the air cooler	P_{int}	kPa	$\pm 2 \%$
C-2.6	Charge air pressure drop in the air cooler	P_{int}	kPa	$\pm 10 \%$
C-2.7	Exhaust gas pressure at the inlet to the turbocharger or other exhaust gas assisted pressure charger (valid only for engines with a constant pressure system)	P_{g1}	kPa	$\pm 5 \%$
C-2.8	Exhaust gas pressure in the exhaust pipe	P_{g2}	kPa	$\pm 5 \%$
C-2.9	Coolant pressure	P_{cool}	kPa	$\pm 5 \%$
C-2.10	Lubricating oil pressure	P_o	kPa	$\pm 5 \%$
C-2.11	Fuel pressure	P_f	kPa	$\pm 10 \%$
C-3	Temperature			
C-3.1	Air temperature at the engine or pressure charger inlet (ambient temperature)	T_a	K	$\pm 2 \text{ K}$
C-3.2	Charge air temperature after the pressure charger	T_b	K	$\pm 4 \text{ K}$

*The accuracy of each pressure (except the pressure in C-2.1 and C-2.4.2 is given as a percentage of the gauge pressure.

The unit bar may be used instead of kPa.

No.	Parameter	Symbol	Unit	Accuracy
1	2	3	4	5
C-3.3	Charge air temperature after the cooler	T_{int}	K	± 4 K
C-3.4	Exhaust gas temperature at the cylinder outlet	T_g	K	± 25 K
C-3.5	Exhaust gas temperature at the inlet to the turbocharger or other exhaust gas assisted pressure charger	T_{g1}	K	± 25 K
C-3.6	Coolant temperature	T_{cool}	K	± 2 K
C-3.7	Lubricating oil temperature	T_o	K	± 2 K
C-3.8	Fuel temperature	T	K	± 5 K
C-4	Consumptions			
C-4.1	Fuel consumption	G_f	g/s kg/s kg/h	± 3 %
C-4.2	Specific fuel consumption	g_f	g/kW.h g/MJ	± 3 %
C-4.3	Cylinder lubricating oil consumption	G_{cyl}	g/s kg/s kg/h	± 10 %
C-4.4	Specific consumption of cylinder oil	g_{cyl}	g/kW.H g/MJ	± 13 %
C-4.5	Circulating lubricating oil consumption	G_{c1r}	g/s kg/s kg/h	± 10 %
C-4.6	Specific consumption of circulating lubricating oil	g_{c1r}	g/kW.h g/MJ	± 13 %
C-4.7	Air consumption	G_{air}	kg/s kg/h	± 5 %
C-4.8	Cooling fluid flow	G_{cool}	kg/s kg/h	± 10 %
C-4.9	Lubricating oil flow	G_o	kg/s kg/s	± 10 %
C-5	Exhaust gas emission characteristics			
C-5.1	Smoke index*	r	Smoke Number	± 0.3 in a scale of 10 Units
C-5.2	Smoke opacity :			
	a) Light obscurement by undiluted gas†	N	%	± 5 %
	b) Coefficient of light absorption‡	k	m^{-1}	± 5 %

*For automatic continuous measurement, the accuracy in C-5.1 may be ± 0.6 on a scale of 10 units.

†Measured over the entire cross-section of the exhaust plume close to the point of exit from the exhaust pipe or over a defined length of the smoke column, the linear dimension in each case being denoted by L , expressed in metres.

‡The value k is given by the equation :

$$k = \frac{-1}{L} \log_e \left(1 - \frac{N}{100} \right)$$

where N is the reading of smoke opacity on a linear scale from 0 to 100 units.

<i>No.</i>	<i>Parameter</i>	<i>Symbol</i>	<i>Unit</i>	<i>Accuracy</i>
1	2	3	4	5
C-5.3	Soot content	C	g/m ³	± 10 %
C-5.4	Gaseous emission composition	c_i^*	% or ppm	†
C-5.5	Emission rate	E_i^*	g/h	†
C-5.6	Specific emission	e_i^*	g/kW·h	†

*'i' is the suffix of an individual component of the exhaust gas.

†As per agreement between the manufacturer and the purchaser.

Standard Mark

The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act, 1986* and the Rules and Regulations made thereunder. The Standard Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well defined system of inspection, testing and quality control which is devised and supervised by BIS and operated by the producer. Standard marked products are also continuously checked by BIS for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act, 1986* to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Copyright

BIS has the copyright of all its publications. No part of these publications may be reproduced in any form without the prior permission in writing of BIS. This does not preclude the free use, in the course of implementing the standard, of necessary details, such as symbols and sizes, type or grade designations. Enquiries relating to copyright be addressed to the Director (Publications), BIS.

Revision of Indian Standards

Indian Standards are reviewed periodically and revised, when necessary and amendments, if any, are issued from time to time. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition. Comments on this Indian Standard may be sent to BIS giving the following reference:

Doc : No. TED 2 (4978)

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters :

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones : 331 01 31, 331 13 75

Telegrams : Manaksanstha
(Common to all Offices)

Regional Offices :

	Telephone
Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg NEW DELHI 110002	{ 331 01 31 331 13 75
Eastern : 1/14 C. I. T. Scheme VII M, V. I. P. Road, Maniktola CALCUTTA 700054	87 86 62
Northern : SCO 445-446, Sector 35-C, CHANDIGARH 160036	53 38 43
Southern : C. I. T. Campus, IV Cross Road, MADRAS 600113	41 29 16
Western : Manakalaya, E9 MIDC, Marol, Andheri (East) BOMBAY 400093	6 32 92 95

Branches : AHMADABAD. BANGALORE. BHOPAL. BHUBANESWAR.
COIMBATORE. FARIDABAD. GHAZIABAD. GUWAHATI.
HYDERABAD. JAIPUR. KANPUR. PATNA. THIRUVANATHAPURAM.